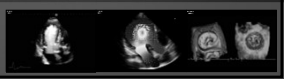
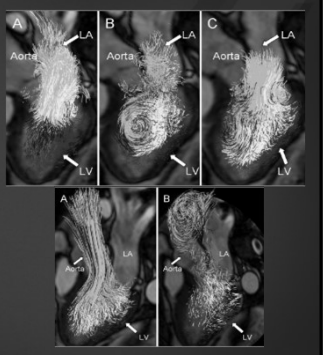
Hemodynamic solution using Vector Flow Mapping (VFM)

Takashiro Hirano
Hitachi Ltd, Healthcare Business Unit

Redefining the Vision of Cardiovascular Ultrasound



Flow in Chamber



Eriksson et al. Journal of Cardiovascular Magnetic Resonance 2010, 12:9

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Hemodynamic Evaluation

Emerging Trends in CV Flow Visualization

Partho P. Sengupta, MD, DM,* Gianni Pedrizzetti, PhD,† Philip J. Kilner, MD‡
Arash Kheradvar, MD, PhD,§ Tino Ebbers, PhD,‖ Giovanni Tonti, MD,¶
Alan G. Fraser, MB,# Jagat Narula, MD, PhD*
New York, New York; Trieste, Italy; London, United Kingdom; Irvine, California; Linköping, Sweden; Sulmona (AQ), Italy; and Cardiff, United Kingdom

Table 2. Clinical Applications of Flow Visualization Techniques

Clinical Condition	Potential Applications
LV systolic function	Paths and kinetic energy changes of blood flowing into the left ventricle for understanding development and progression of dilated/hypertrophic LV remodeling, assessing stagnant flow and risk of thrombus formation, assessment of LV dyssynchrony, optimization of resynchronization therapy and assist devices
LV diastolic function	Transmitral flow patterns and spatial distribution of intraventricular pressure gradients, shear stress, and kinetic energy
Atrial function	Flow features for stratifying risks of left atrial clot formation, efficiency of flow in congenital heart diseases, including Fontan circulation
Valvular diseases	Relationship of regurgitation jet on turbulence and energy dissipation, effects of valve repair and prosthetic replacement surgery on valvular flow direction and LV remodeling
Aorta	Relationship of flow characteristics and shear stress with risks of aortic atherosclerosis, risks of aortic dilation and dissection in Marfan syndrome, retrograde flow from descending aorta and risks of cerebral embolism, optimization of aortic reconstruction surgeries
Pulmonary artery	Characterization of flow features associated with pulmonary artery remodeling in pulmonary hypertension and thrombus formation

LV = left ventricular.

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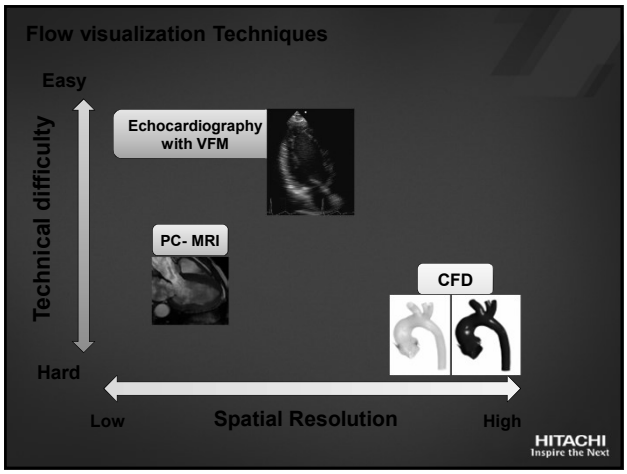
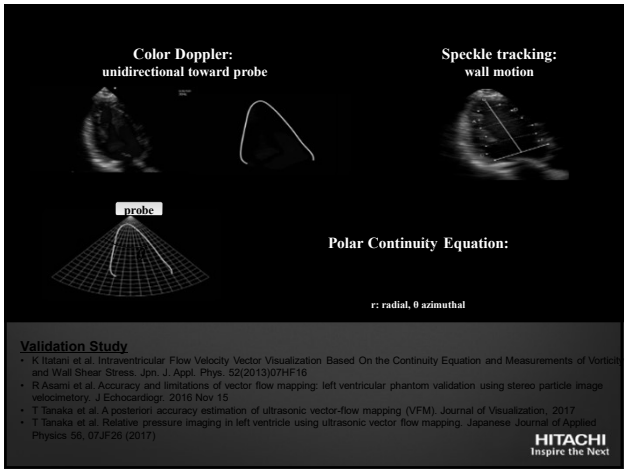
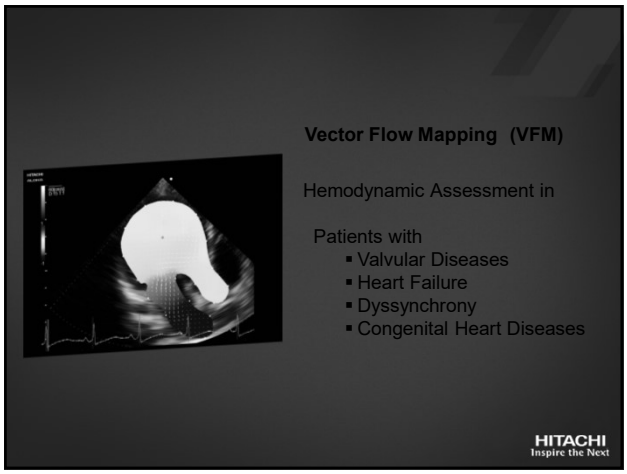
Flow visualization Techniques

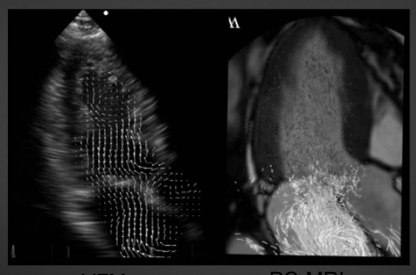






Vortex in LV: Normal subject

Abe H, et al. EHJ Cardiovasc Imaging 2013.
Eriksson J et al. EHJ – Cardiovascular Imaging (2013) 14, 417–424



VFM PC-MRI

Courtesy of: Prof. Lancellotti, Dr. Kou, University of Liège, Department of Cardiology

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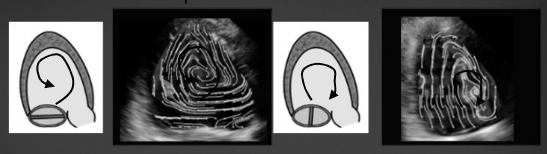
Flow Efficiency after Mitral Valve Surgery

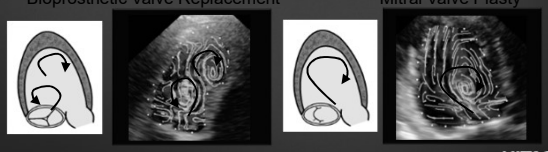
Mechanical Valve Replacement
Anti-anatomical position

Mechanical Valve Replacement
Anatomical Position



Bioprosthetic Valve Replacement

Mitral Valve Plasty



Heart Vessels (2017) 32:1123-1129

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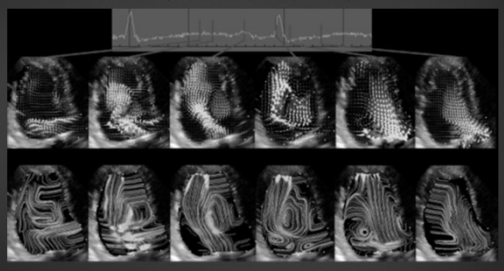
Flow Efficiency after Mitral Valve Surgery

Flow Patter with Mechanical Valve Replacement anatomical position (**Clockwise Rotation**)



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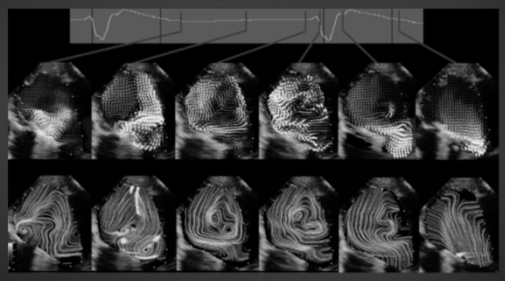
Flow Efficiency after Mitral Valve Surgery

Flow Patter with Mechanical Valve Replacement
Anti-anatomical position (**Counter-Closewise Rotation**)



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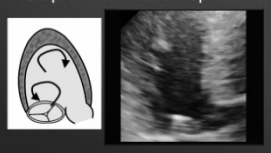
Flow Efficiency after Mitral Valve Surgery

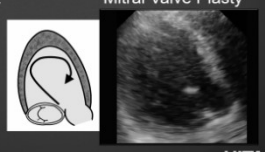
Mechanical Valve Replacement
Anti-anatomical position

Mechanical Valve Replacement
Anatomical Position

Bioprosthetic Valve Replacement



Mitral Valve Plasty



Heart Vessels (2017) 32:1123–1129

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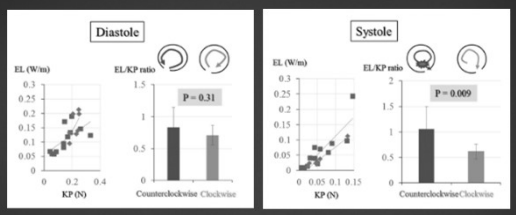
Flow Efficiency after Mitral Valve Surgery



- **Optimizing intraventricular blood flow to preserve efficient cardiac output is essential in cardiovascular surgery.**
- **"Counter-Clockwise" vortex flow causes additional burden(cardiac workload) to convey blood flow to whole body.**
- **Energy Loss was great practical importance to pay attention to the direction of the vortex in the ventricular chamber after mitral valve surgery.**

Heart Vessels (2017) 32:1123-1129

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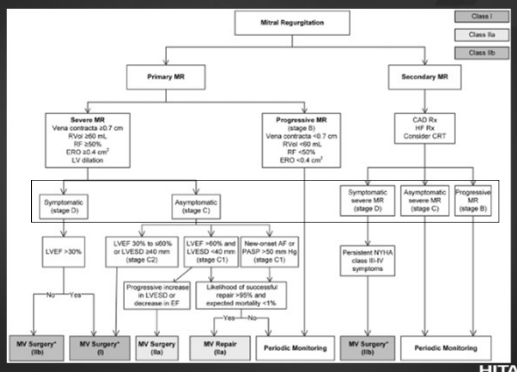
AHA/ACC Guideline for the Management of Patients With Valvular Heart Disease



R.Nishimura et al. AHA/ACC GUIDELINE, Circulation 2017

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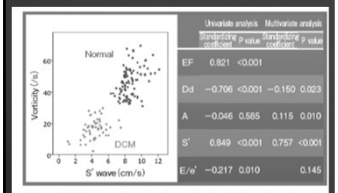
Clinical Outcome in patients with heart failure

Vortex intensity correlates with cardiac function and clinical outcomes in heart failure



	Univariate analysis		Multivariate analysis	
	standardized coefficient	P value	standardized coefficient	P value
EF	0.821	<0.001		
Dd	−0.706	<0.001	−0.150	0.023
A	−0.046	0.585	0.115	0.010
S'	0.849	<0.001	0.757	<0.001
E/e'	−0.217	0.010		0.145

Figure 6 Determinants of vorticity during isovolumic contraction.

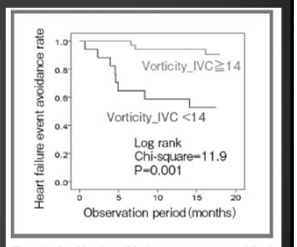


Figure 8 Kaplan-Meier curves stratified by vorticity during isovolumic contraction.

Dr.Tokuhisa Uejima
The Japanese Society of Echocardiography, 28th Annual Scientific Meeting, Luncheon Seminar 7

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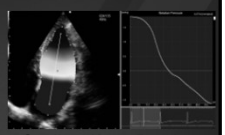
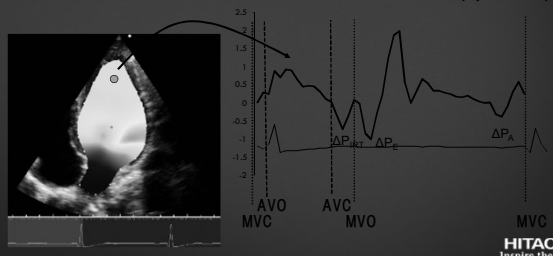
LV Suction differentiate patient with and without HF

IVPG(Intraventricular Pressure Gradient) Using Relative Pressure Imaging(RPI)



Intraventricular Pressure Gradient (Apex-Base)



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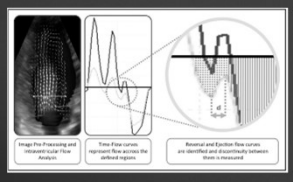
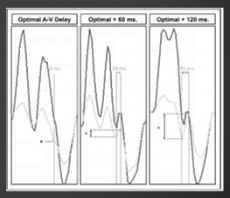
Flow Continuity in patients with dyssynchrony

Mitral-Aortic Flow Reversal in Cardiac Resynchronization Therapy

Coupling With Ejection and Impact of Variations in Atrioventricular Delay

Daniel Rodríguez Muñoz, MD; José Luis Moya Mur, MD, PhD; Javier Moreno, MD, PhD; Covadonga Fernández-Golfín, MD; Eduardo Franco, MD, PhD; Bostjan Berlot, MD; Juan Manuel Monteagudo, MD; Roberto Matía Francés, MD, PhD; Antonio Hernández Madrid, MD, PhD; José Luis Zamorano, MD, PhD





Discontinuity caused by notch due to Vortex flow during ICT

Circ Arrhythm Electrophysiol. 2017;10:e004927

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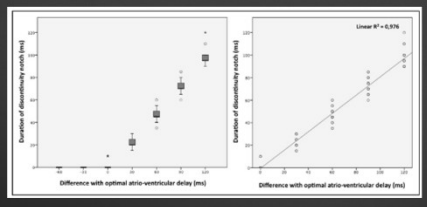

Circ Arrhythm Electrophysiol. 2017;10:e004927

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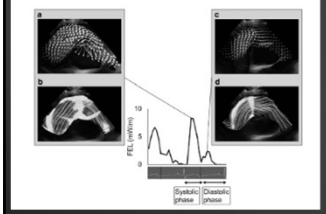
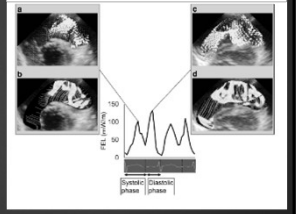
Flow Energy Loss as a Predictive Parameter for Right Ventricular Deterioration Caused by Pulmonary Regurgitation After Tetralogy of Fallot Repair

Miyuki Shibata[1] · Keiichi Itatani[1,2] · Taiyu Hayashi[2] · Takashi Honda[4] · Atsushi Kitagawa[4] · Kagami Miyaji[2] · Minoru Ono[1]

Normal Pattern



Turbulence Flow due to PS and PR



Pediatric Cardiology (2018) 39: 731-742

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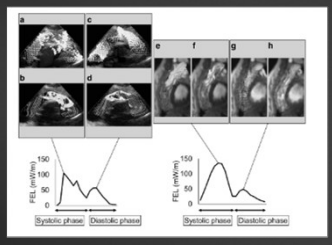

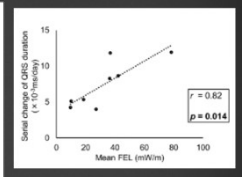

- VFM has comparable data compared with PC-MRI
- PS and PR causes turbulence inside RVOT is major cause of RV deterioration after TOF repair.
- Energy Loss enables to predict deterioration of RV function. correlate with serial change of QRS duration

Pediatric Cardiology (2018) 39: 731-742

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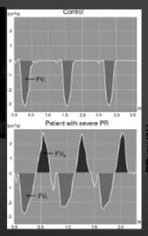
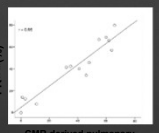
Quantification of Pulmonary Regurgitation by Vector Flow Mapping in Congenital Heart Patients after Repair of Right Ventricular Outflow Obstruction: A Preliminary Study

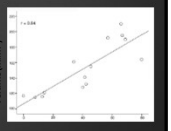
Ashley Hoi-man To, MBBS, Vivian Wing-yi Li, MPhil, Ming-Yen Ng, BMedSci, BMBS, and Yiu-Fai Cheung, MD, *Hong Kong, China*



Validation study compared to CMR

VFM-derived Pulmonary regurgitation ratio (%) was well correlated with CMR-derived PR fraction and RV end-diastolic Volume.





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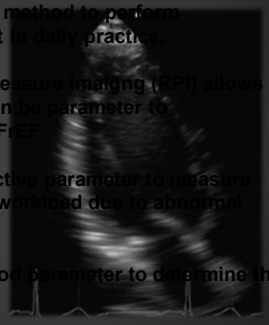
Hemodynamic Assessment gives

- **VFM is the one of the best method to perform hemodynamic assessment in daily practice.**
- **IVPG based on Relative Pressure Imaging (RPI) allows to show LV suction and can be parameter to differentiate HFpEF and HFrEF.**
- **Energy Loss can be predictive parameter to measure Flow inefficiency/Cardiac workload due to abnormal vortex.**
- **Flow Continuity can be good parameter to determine the optimal timing of CRT.**



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